Aerosol Forcing over China and Regional Climate Change

Yunfeng Luo
National natural sciences foundation of China, Beijing, China

Wenqin Zhu , Longxun Chen, Xiuji Zhou
Chinese Academy of Meteorological Sciences, Beijing, China

Guoyu Ren, Zijiang Zhou
National meteorological center, Beijing, China

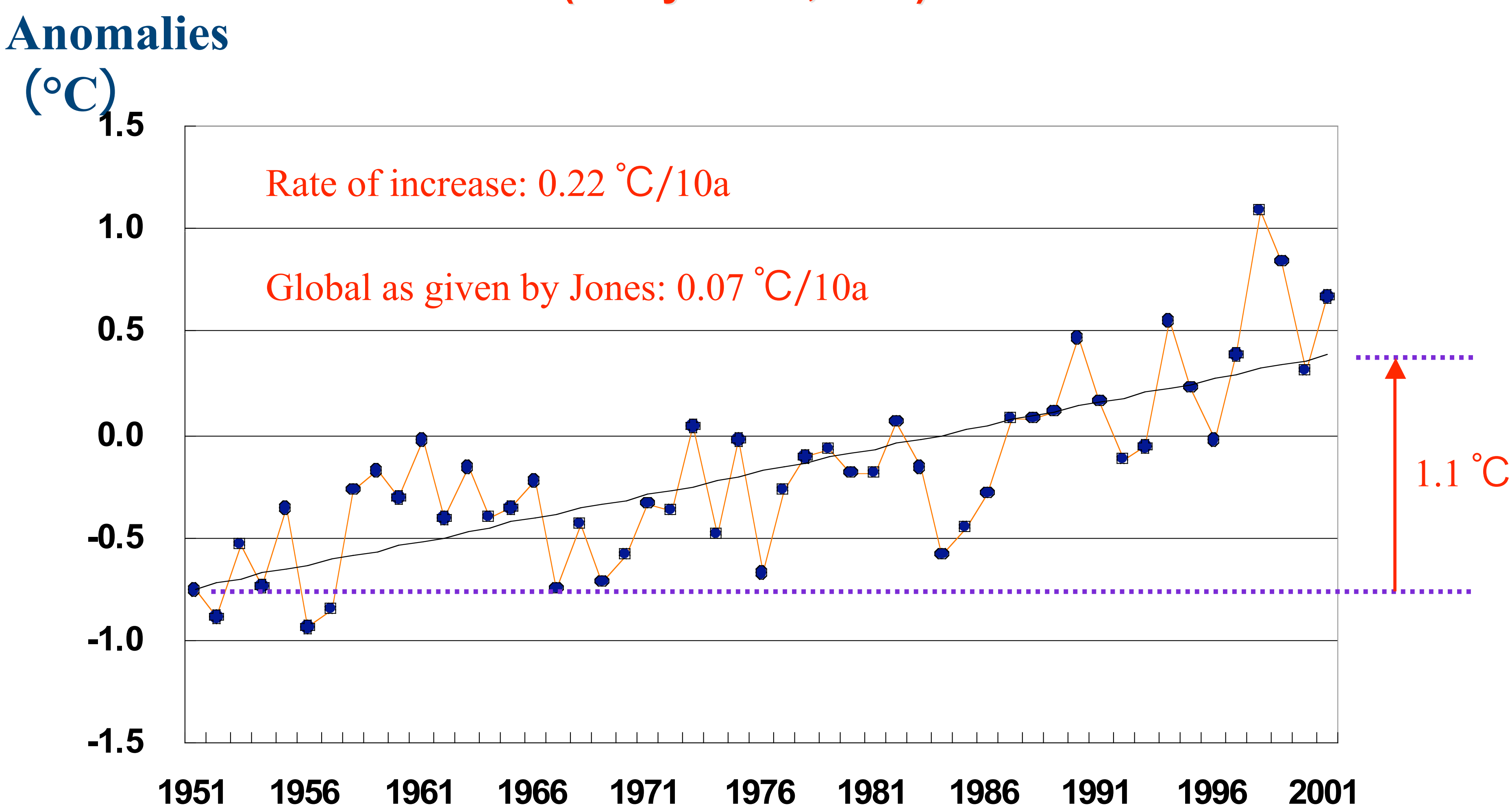
Jinhuan Qiu
Institute of Atmospheric Physics, Chinese Academy of Science, Beijing, China

Workshop of Air Pollution as Climate Forcing 4-6 April, 2005 , Hawaii

Outline

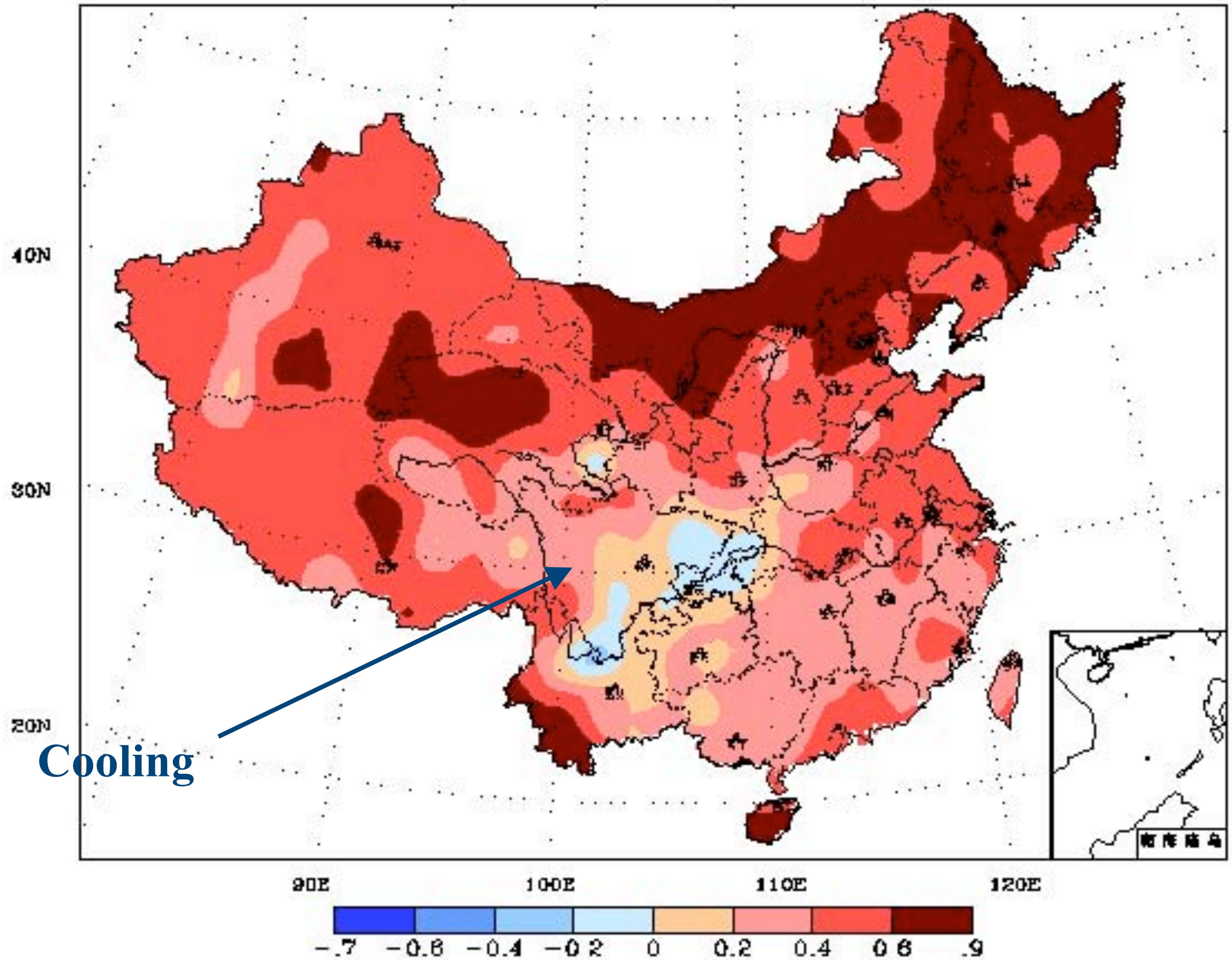
- Chinese regional climate change
  (Courtesy of the Draft for IPCC IV)
- Aerosol data record and model simulation
- Prospects

Change in annual mean temperature in China (1951-2001)
(Guoyu Ren,2005)



60% of the warming in the last 30% years of the period, and 9 warmest years in the last 12 years, with 1998 the warmest year.

Warning in North, West, and South, cooling in Southwest

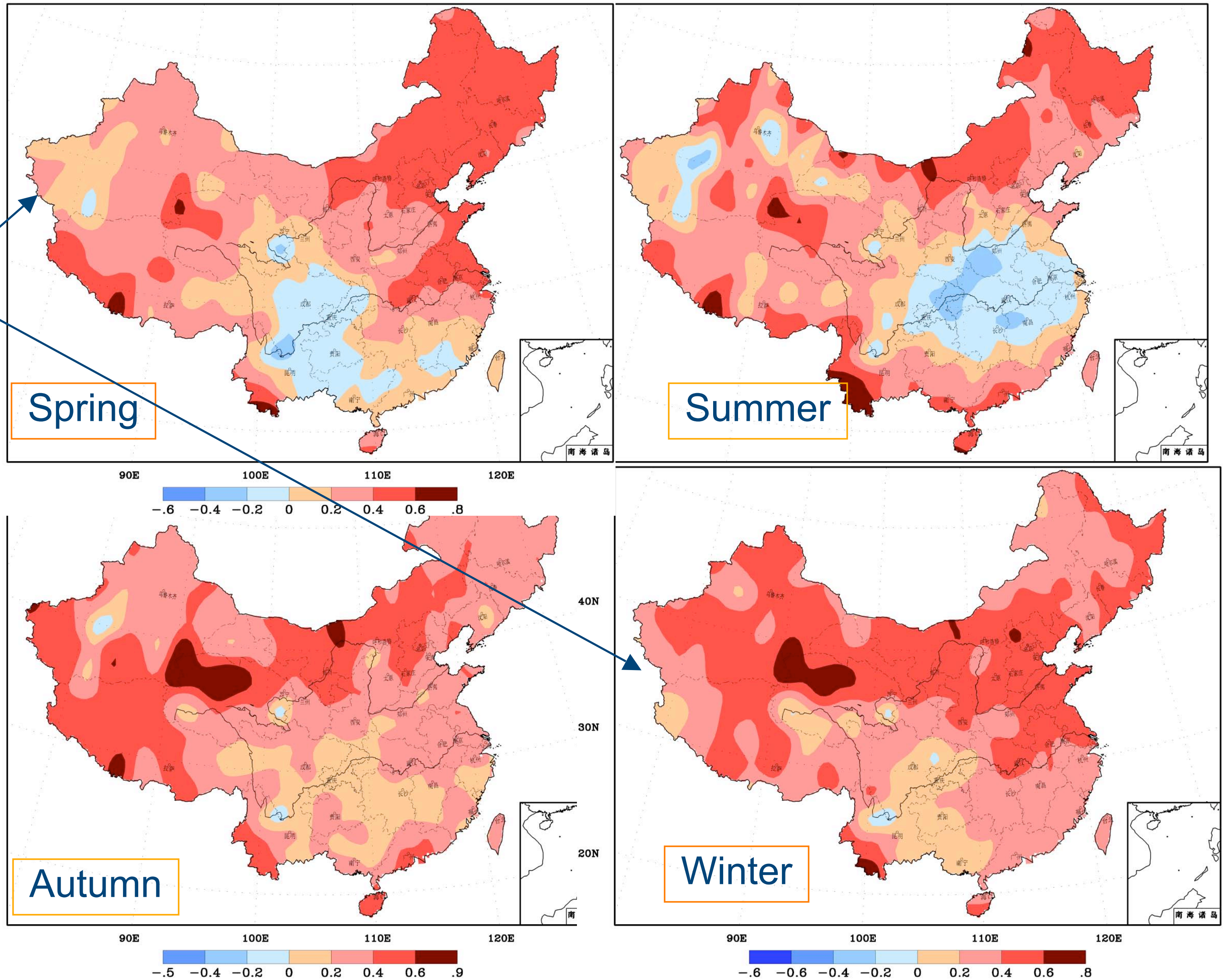


Tendency of annual mean temperature in China from 1951 to 2001

Guoyu Ren (2005)

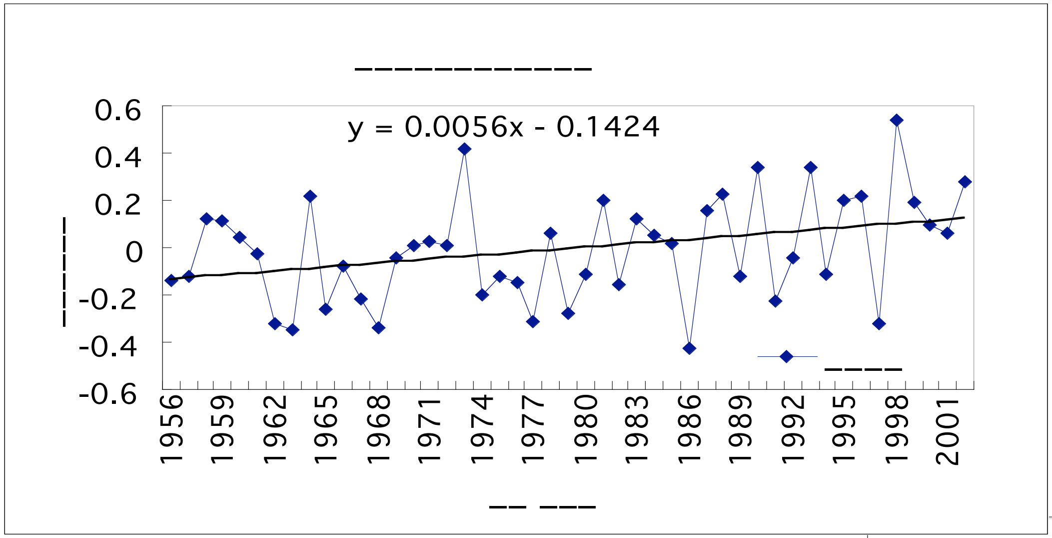
cooling tendency in southwest and the middle and lower reaches of the Yangzi River in summer.

warming mainly in the winter and spring



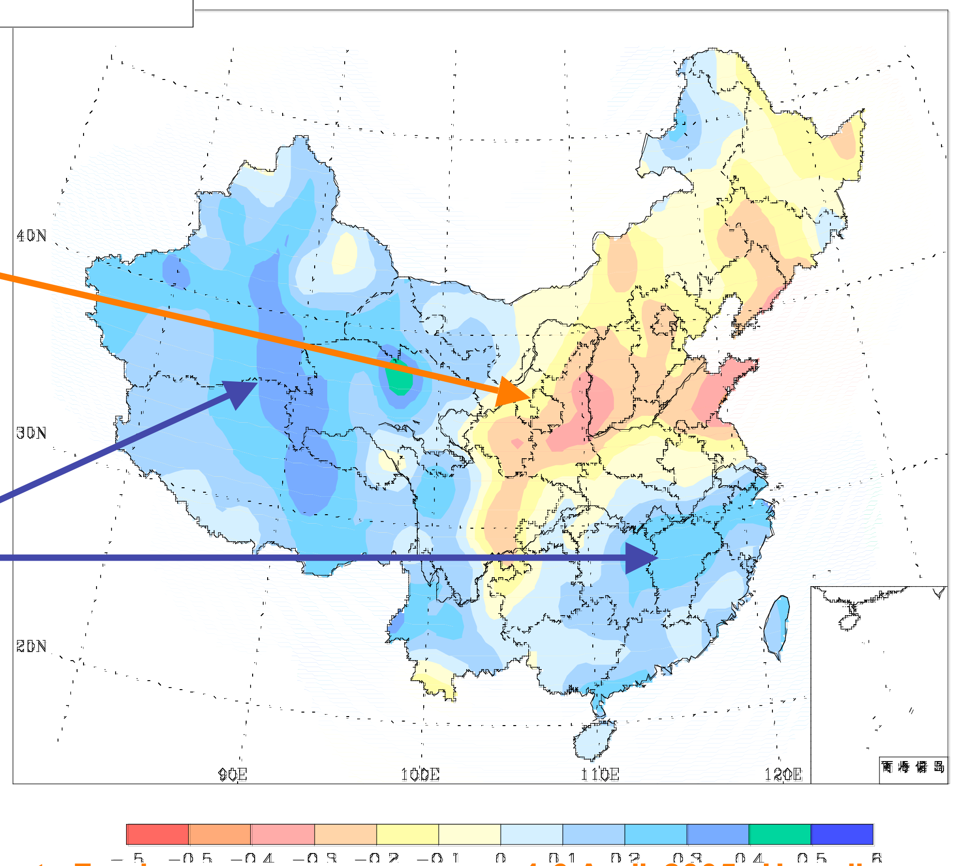
Tendency of seasonal mean temperature in China from 1951 to 2001

Guoyu Ren (2005)



Change in annual precipitation in China (1956-2002)

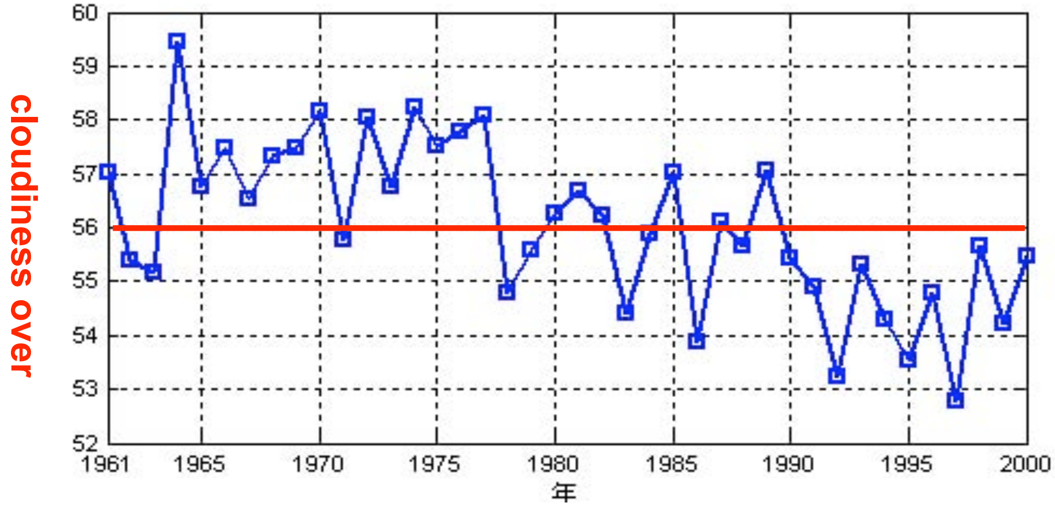
Tendency of annual precipitation in China from 1956 to 2002



Northern China, the eastern part of Western China, and the southern part of Northeast China, the annual precipitation has a decreasing tendency.

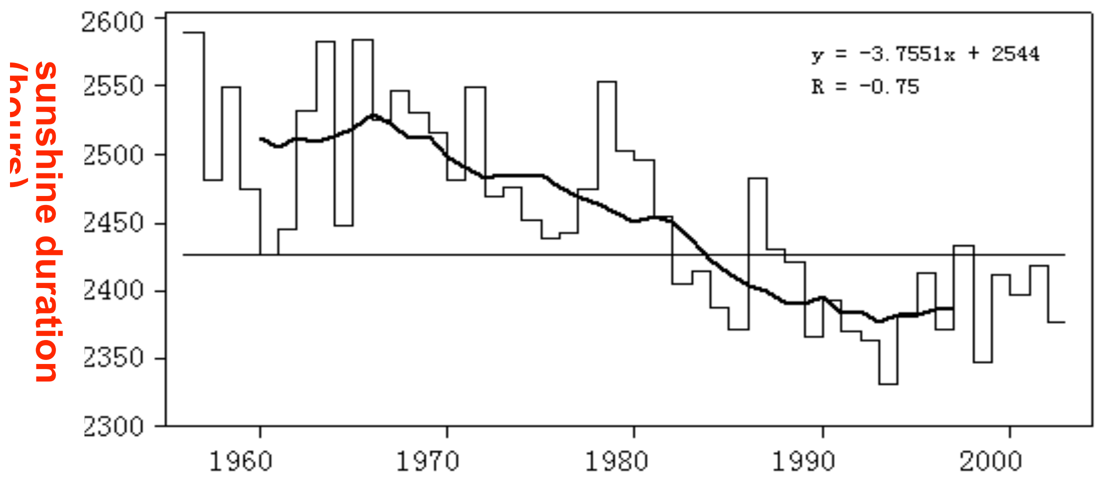
In the middle and lower reaches of Yangzi River and Western China, the increase is obvious.

Guoyu Ren (2005)



Change in cloudiness over China (1961-2000)

Wang yin (2005)



Overall cloudiness has a decreasing tendency, which is most obvious in Northern China. The annual sunshine duration show obvious decreasing tendencies since the 1970s

Change in annual pan-evaporation, sunshine duration in China from 1956 to 2002, **Guoyu Ren (2005)**

Why does the cooling occur in Southwest and Yangzi River areas of China,?

1. **GHGs increasing => warming**
2. Aerosol increasing => cooling?

Aerosol data record and model simulation

Aerosol's parameters are the basis for climate forcing

Aerosols

Climate Forcing

δ, α, ω, g…

- **Sophisticated climate model**
- **Chemistry code**
- **Good physical parameterization scheme**

- **Time serial**
- **Space distribution**
- **Vertical profile**

Retrieve methods are useful

Using rich conventional meteorological data retrieve AOD, and then verify by limited real observational are a way to get AOD for purpose of its climate forcing research

Real observation data is rare scary, esp. for long-time serial and Space distribution in China

Aerosol optical depth

• Qiu (1997; 1998) retrieved 0.75 μm aerosol optical depth (AOD) based on total direct solar radiation, surface pressure, vapor pressure and ozone amount.

10 stations from 1980-1994

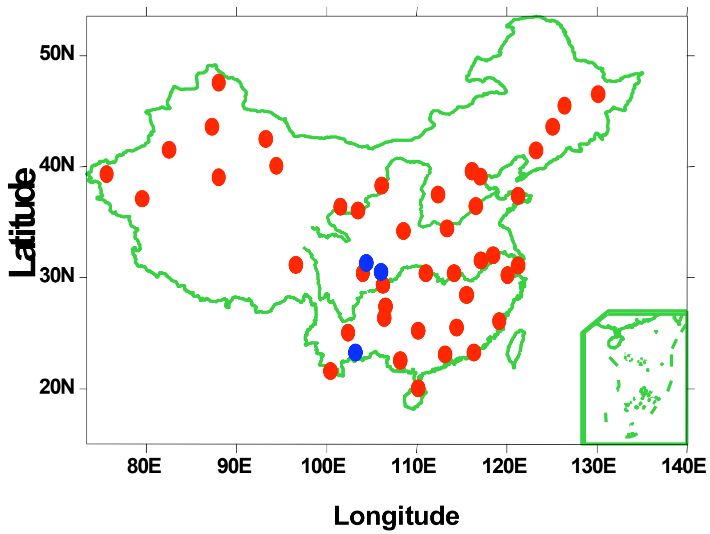
Qiu J., A method to determine atmospheric aerosol optical depth using total direct solar radiation, ***J. Atmos. Sci.***, *55*, 744-757, 1998.

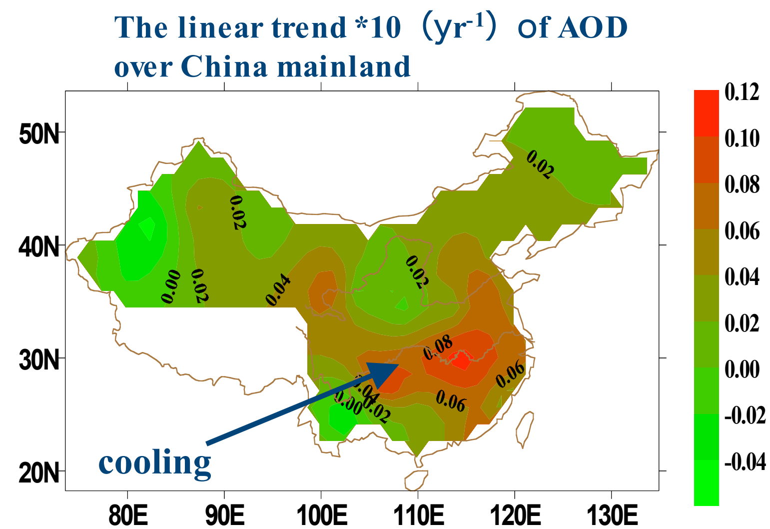
• Luo et al. (2001) extended Qiu (1998) algorithms and retrieved monthly AOD at 0.75 μm from 1961 to 1990 over 46 stations.

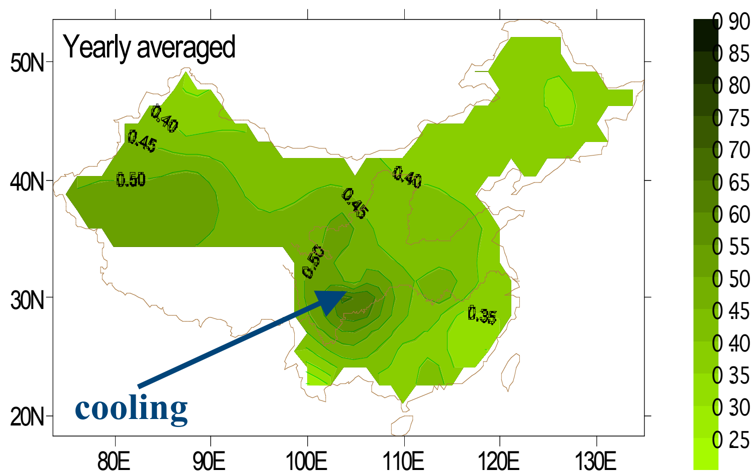
Yunfeng Luo, Daren Lu, Xiuji Zhou, Weiliang Li, Qing He. Characteristics of the spatial distribution and yearly variation of aerosol optical depth over China in last 30 years, 2001, **J. Geophys. Res.** Vol. 106 , No. D13 : 14,501-14,513

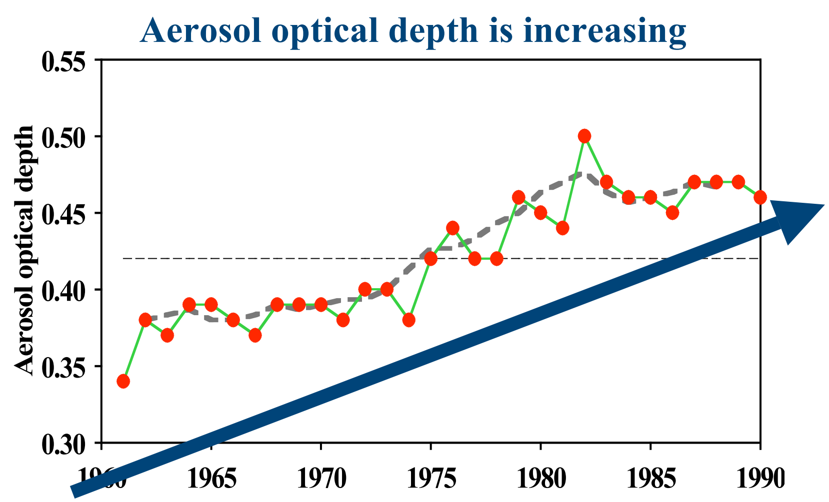
The distribution of yearly mean (1961-1990) aerosol optical depth over China

Luo et al. (2001)









For the same 10 stations,Two algorithms give similar results.

Table 1, comparsion of Qiu (1998) and Luo (2002) algorithms

	Beijin g	**Shen g yang**	**Urumchi**	**Kash i**	**Zhen g zhou**	**Wuha n**	**Shan g hai**	**Kun min g**	**Guan g zhou**	**Geerm u**
Qiu 1997	**0.38**	**0.33**	**0.30**	**0.28**	**0.42**	**0.53**	**0.41**	**0.24**	**0.44**	**0.16**
Luo et al.2001	**0.44**	**0.43**	**0.45**	**0.52**	**0.43**	**0.62**	**0.43**	**0.37**	**0.46**	—

Model simulation

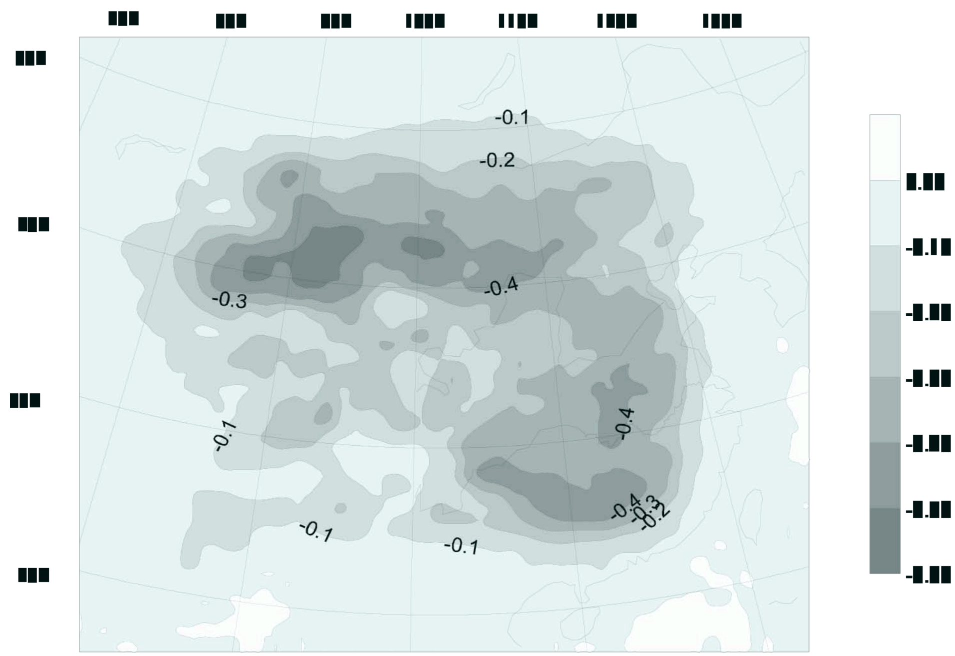
. **China RegCM sensitivity**

Using the retrieved AOD records

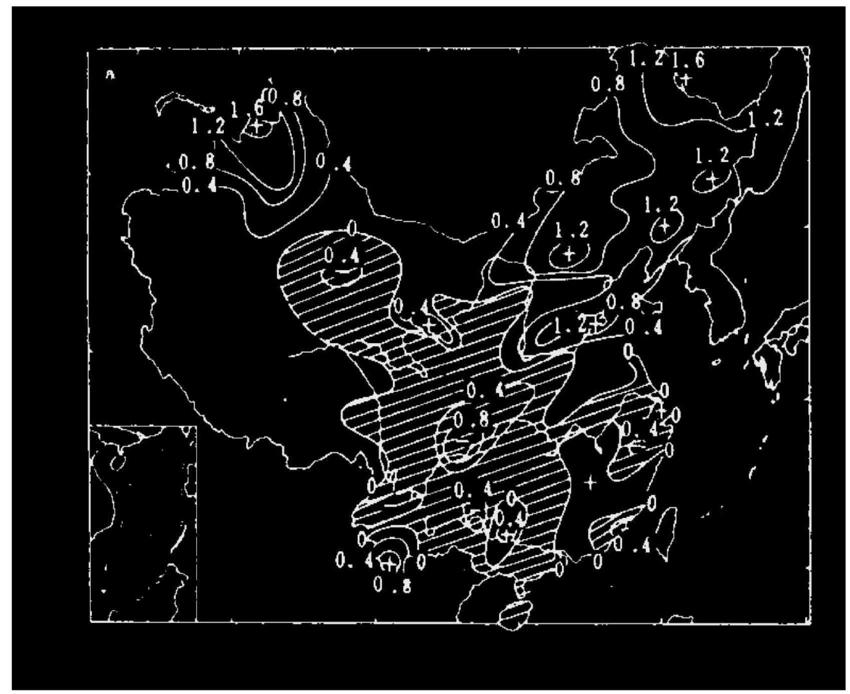
. **Menon and Hansen (2002)**

. **NSFC funded projects**

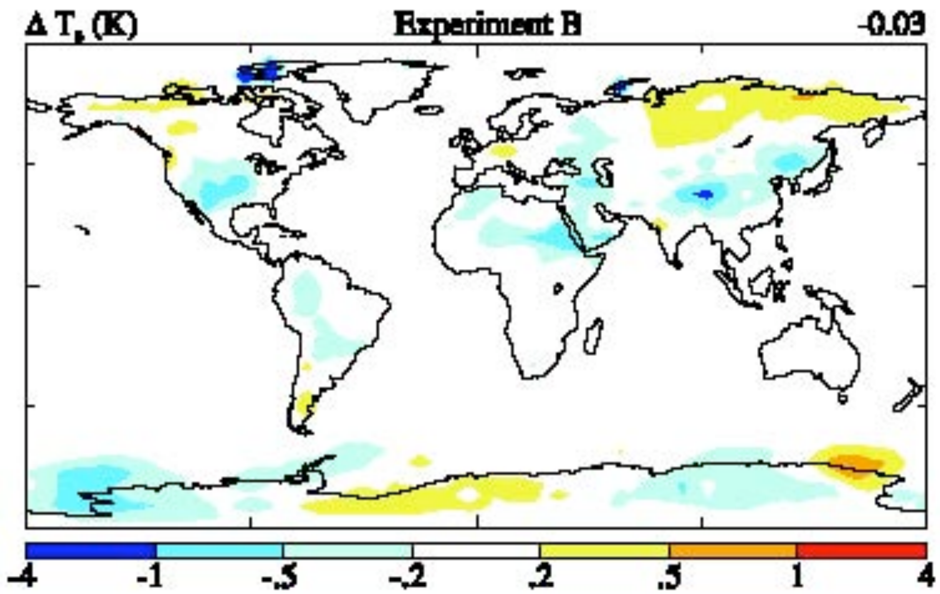
Annual mean surface air temperature response assume SSA=1 Sulfate



Simulated surface air temperature response



Yearly mean temperature change in China during the period from 1950s to 1980s

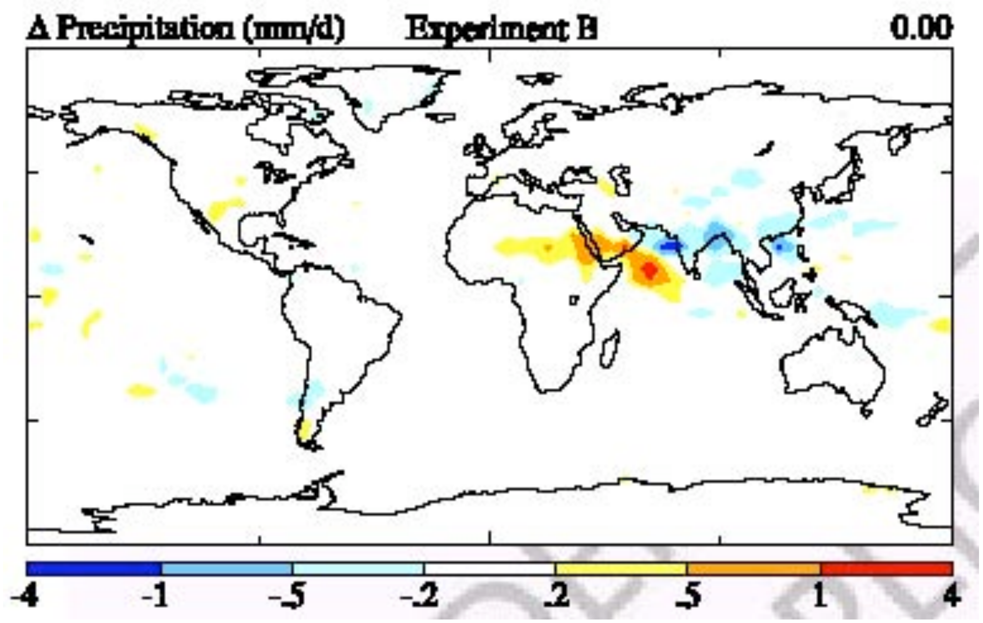


does not yield the strong changes in rainfall patterns and the surface cooling is reduced.

Experiment B

SSA=1.0

pure sulfate aerosols



Experiment A

SSA=0.85

Fig. 2. (A) Simulated JJA surface air temperature change (ΔT_S) for experiments A and B. The significance of these changes is shown in fig. S2. (B) Observed JJA ΔT_S between 1951 and 2000, based on the linear trend. Global mean changes are in the upper right corner.

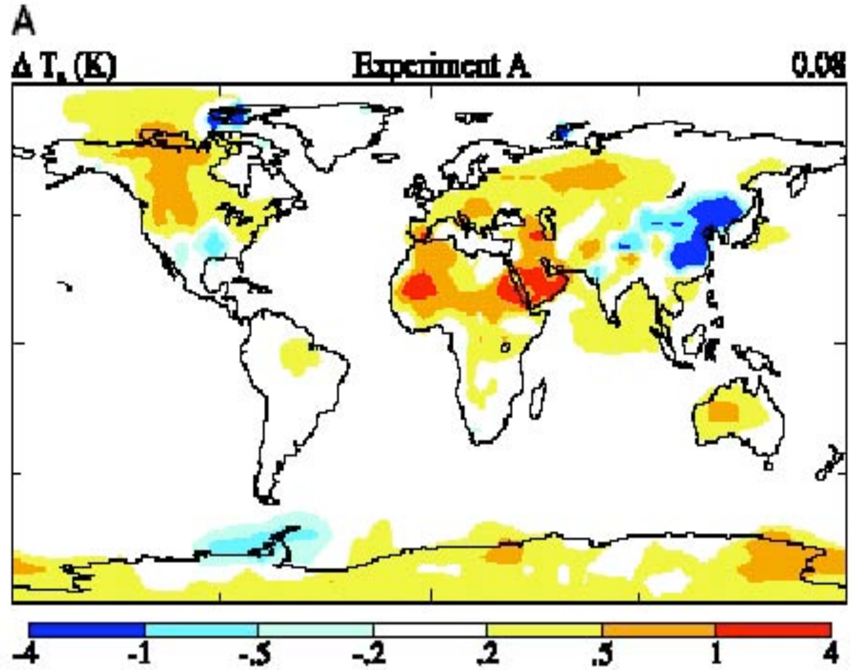
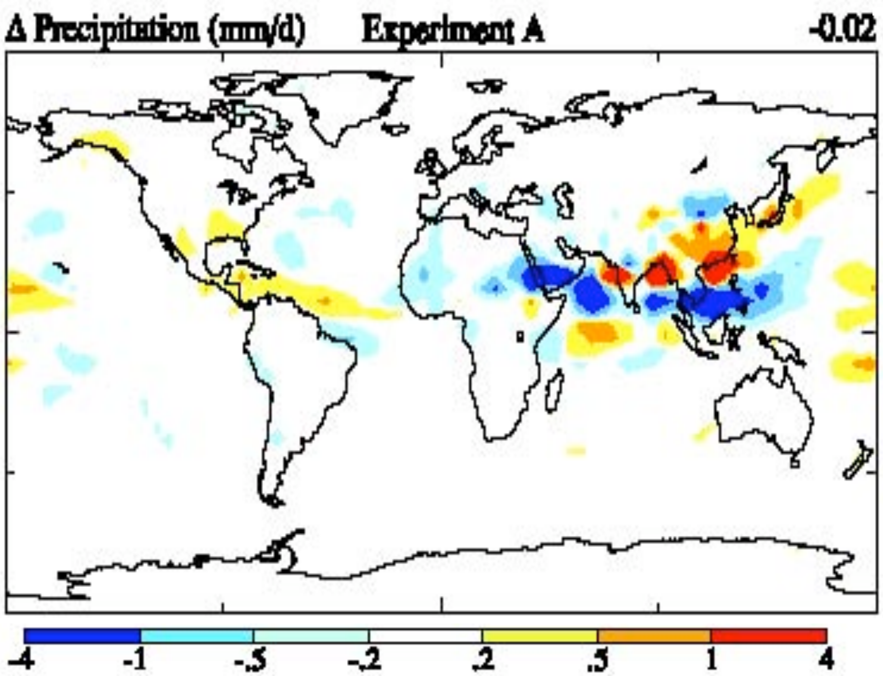


Fig. 3. Same as Fig. 2A, but for precipitation. The significance of these changes is shown in fig. S3.

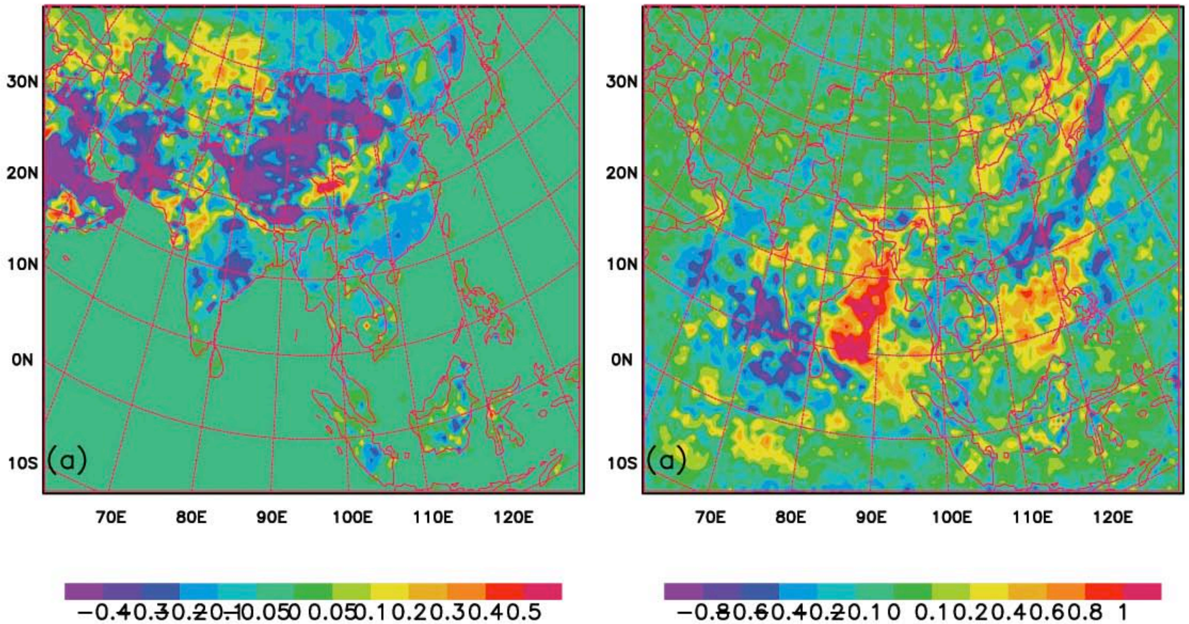


The simulated response patterns of temperature and precipitation are similar with the observation.

NSFC funded projects:

Added TOMS aerosol index , Wu et al. (2004) simulated distribution and radiative forcing and climate response of dust aerosol, simulated results show surface temperature decreased for most areas with dust, which maximum value is within -0.6~-0.8K;

Added David Street's BC distribution, Fu and Wu (2005) explored direct effects of BC using RegCM3 model, simulated results were similar with Manson's results,s



Change of surface temperature (left, K) and precipitation rate (right, mm/day)

Simulated results showed the different SST and other aerosol's parameters are much sensitive to climate response.

Question!

Most of the radiation stations that Qiu and Luo used are all located in the cities, it is thus biased that using these cities' AOD value to describe the AOD distribution for the whole China.

Need more robust AOD results

- **Aerosol optical depth (AOD)**
- **Single scatter albedo (SSA) ?**
- **Aerosol extinction profile ?**
- **…**

Poor known

NSFC funded projects:

For AOD

In 2005, Zhu et al. by using some meteorological parameters, such as visibility and water vapor pressure of 504 stations, to retrieve monthly AOD during the period from 1951 to 2002.

$$AOD_\lambda = 0.733\left(\frac{3.912}{V} - 0.0116\right)\left(\frac{0.75}{\lambda}\right)^{2-\upsilon^*}\left[H_1\left(e^{-\frac{z}{H_1}} - e^{-\frac{5.5}{H_1}}\right) + 12.5e^{-\frac{5.5}{H_1}} + H_2 e^{-\frac{5.5}{H_1}}\right]f$$

Where, V is the visibility at sea level;

Z is the height above sea level; V*=3.0, Jung spectral parameter;,

H_1=0.866+0.022V(km), and H_2=3.77(km).

V can be derived from surface visibility measurement V_Z at the height of Z:

$$V_z = 3.912\left[0.0116 - 0.00099z + \left(\frac{3.912}{V} - 0.0116\right)e^{-\frac{z}{(0.886+0.222V)}}\right]^{-1}$$

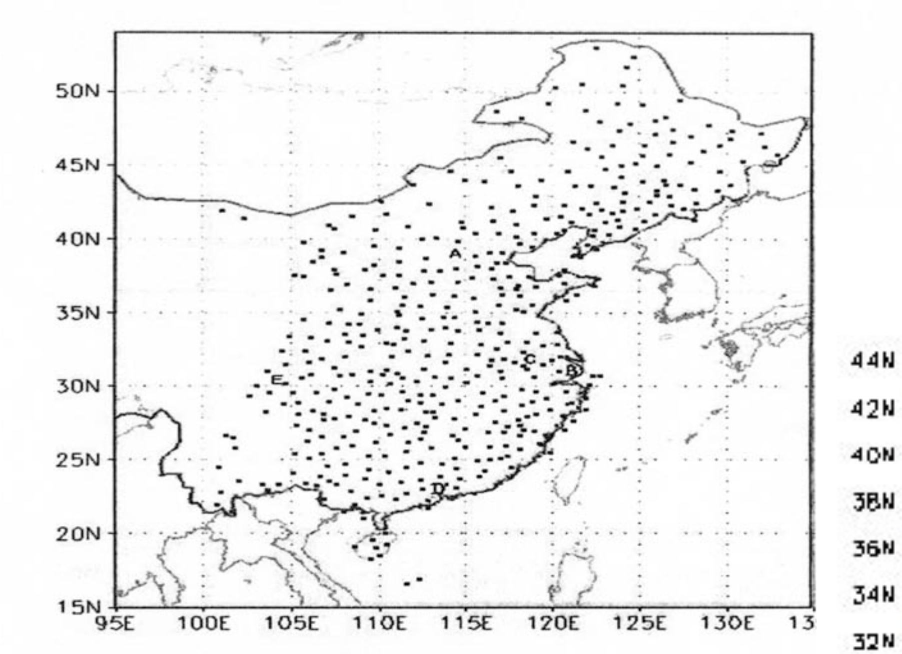
The calibration coefficient f can be written as:

$$f = e^{(0.42-0.0046 p_w + 0.015 V_z)\exp(-0.0047 V_z^2 / p_w)}$$ for north-east China

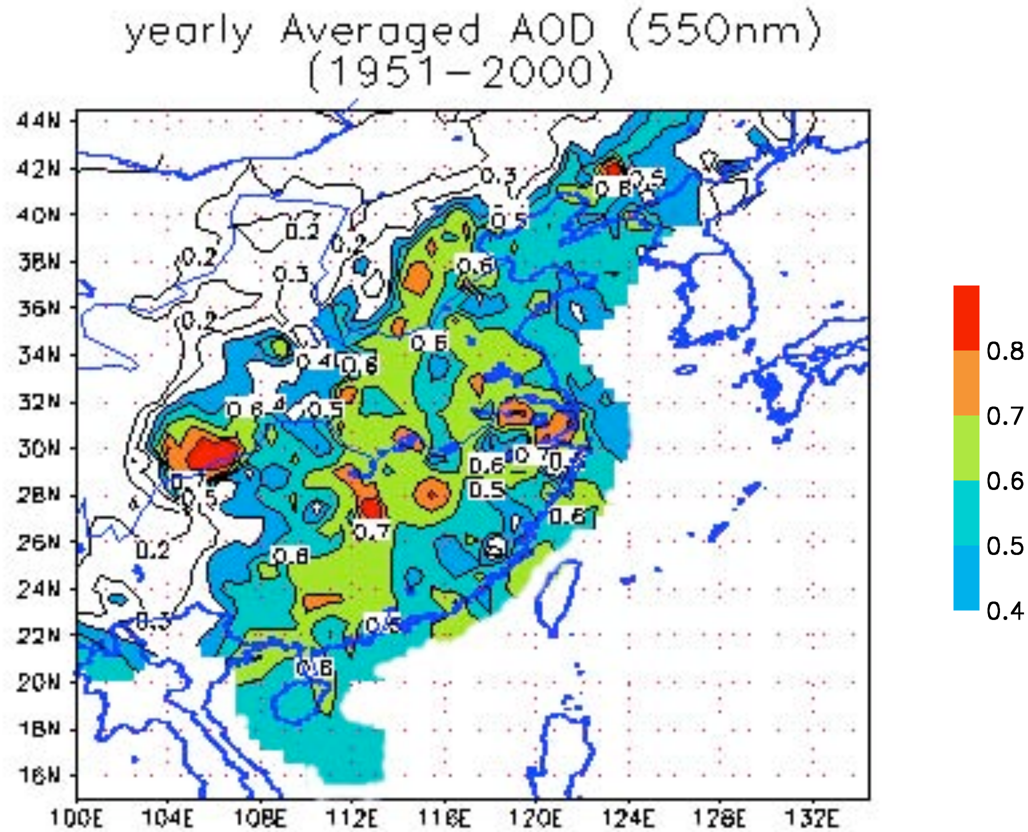
$$f = e^{-0.32+0.02V_z}$$ for other region of China

Method

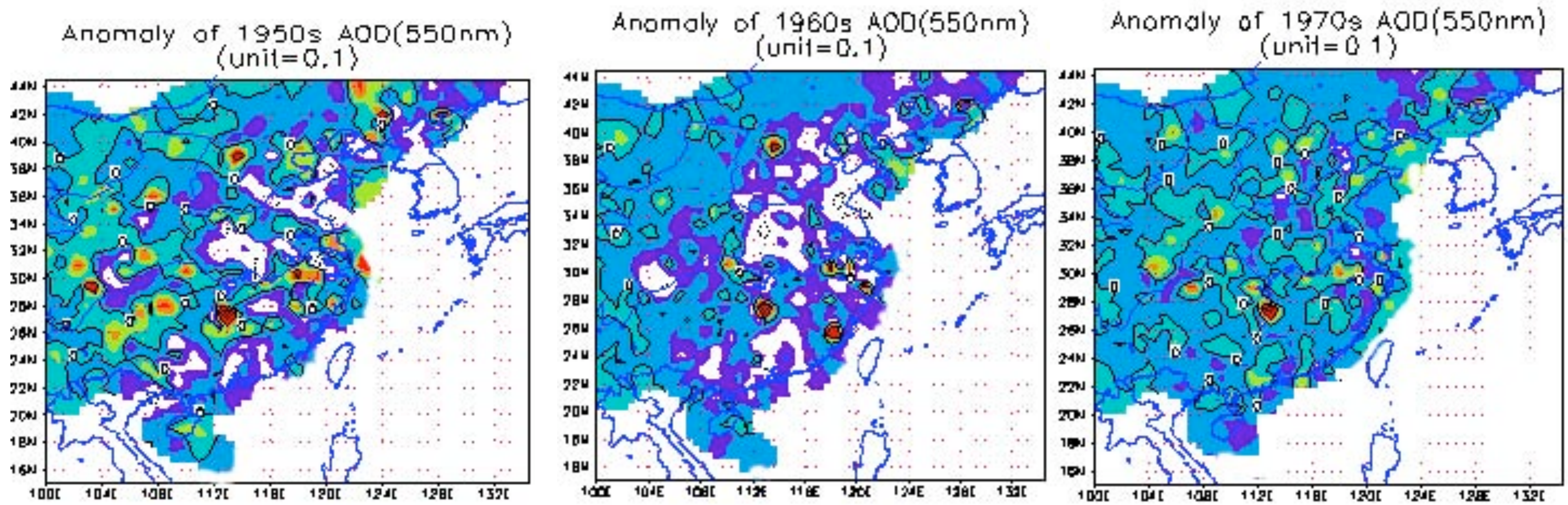
Wenqin Zhu , Longxun Chen, Xiuji Zhou, Yunfeng Luo, Zijiang Zhou, Variation of atmospheric aerosols optical depth and its relationship with climate change in east of 100° E of China during recent 50 years. **2005,Submitted**

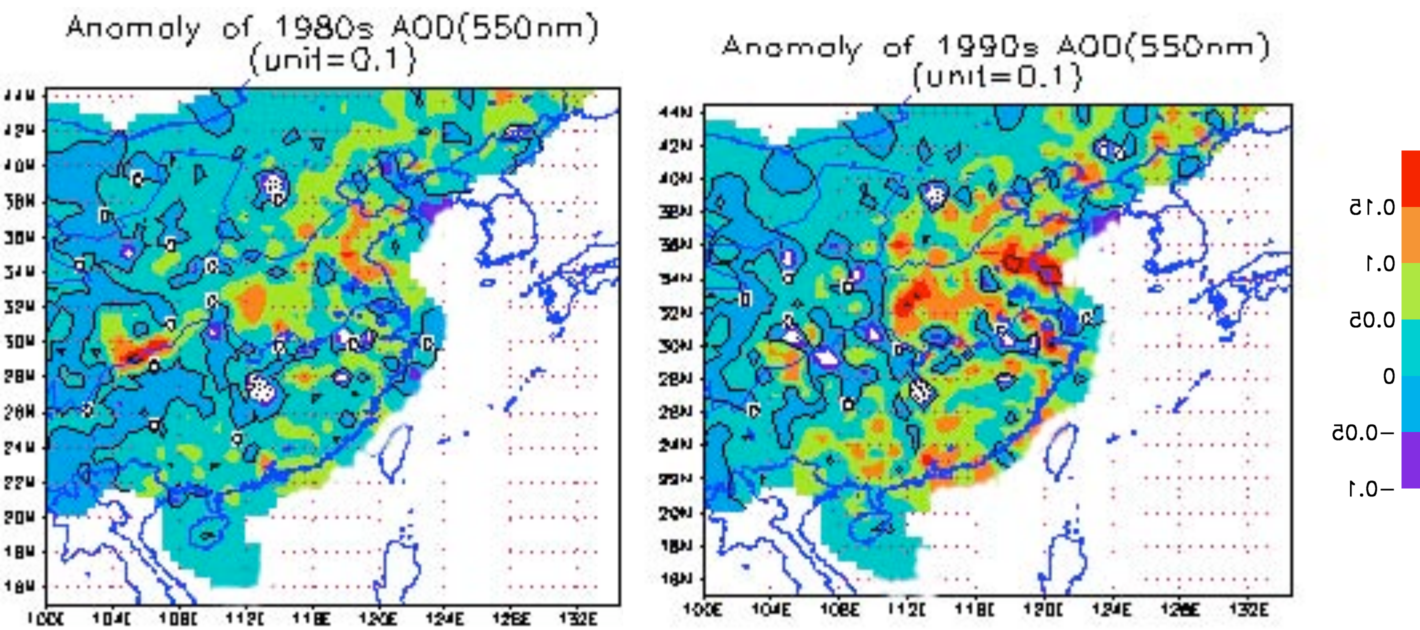


Distribution of stations location (504)



The distribution of averaged AOD in 1951-2000





Although they have uncertainties,this was a creative ideas.

Distribution of decadal anomaly of AOD

NSFC funded projects:

For SST

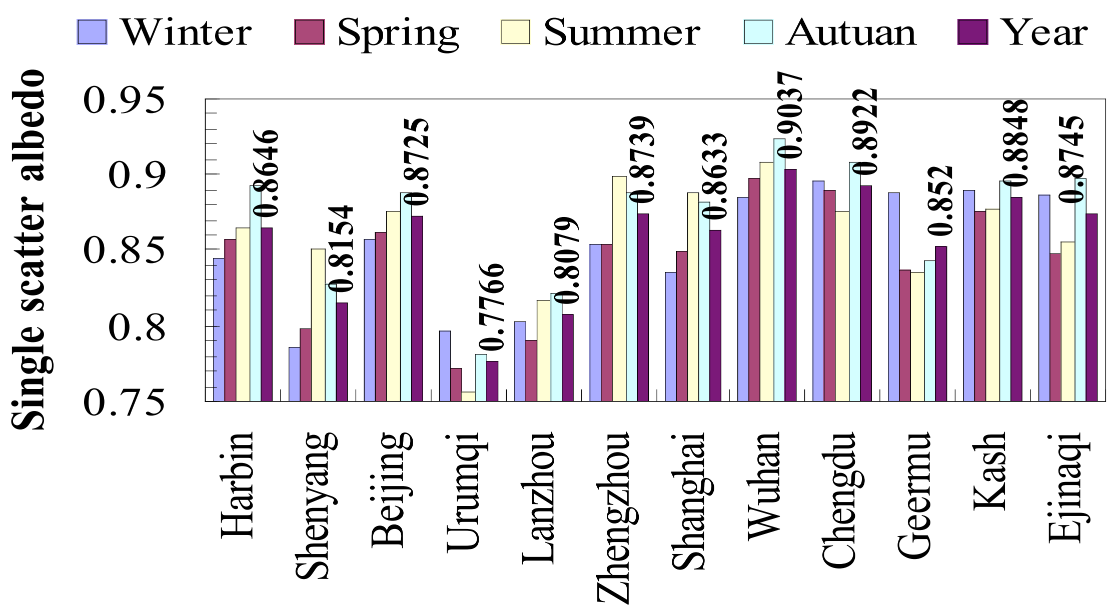
Qiu et al. expand they inversion method to retrieve SST and exponent-type aerosol extinction profile

Broadband radiation method (BRM):

Pyranometer+pyrheliometer data⇒ Diffuse radiation ⇒Aerosol imaginary part and SSA

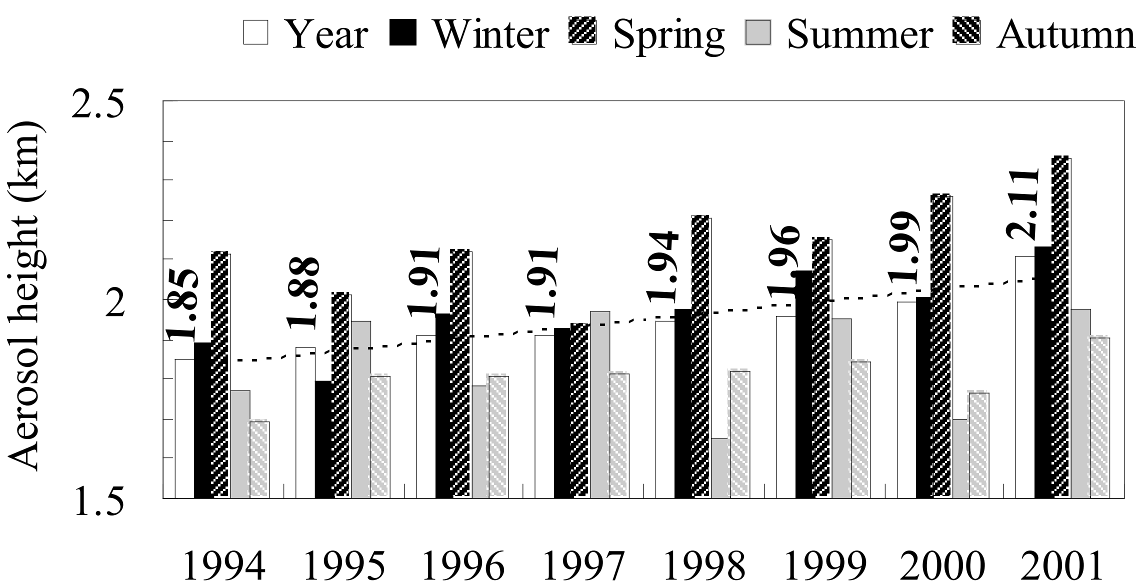
Qiu et al., Tellus, 2001; J. Appl.Meteo., 2003

Qiu J., Yang L., and Zhang X. 2004,



- **Total mean SSA：0.864**
- **Urumqi：0.777**
- **Wuhan: 0.904**
- **Beijing ：0.872**
- **Shenyang：0.815；**
- **Small SSA during winter over some sites such as Shenyang**

AOD (pyrheliometer or sunphotometer measurements) and visibility data ⇒ Scaling height of tropospheric aerosol ⇒ exponent-type aerosol extinction profile



11-site-mean aerosol scaling heights during 1994-2001

•Increasing trend ⇒ shifting-up trend of aerosol particles

•Larger height in spring⇒ Sand-dust effect!

Qiu, Zong and Zhang, 2005, Submitted

Summary

In China:

- Regional climate changed clearly
- Consider aerosol’s direct forcing,simulated results is better
- Real observational data of aerosols are still scarce
- Advances in aerosol information retrieve, need further calibration
- Obtained aerosol data were discontiguous spatio-temporally

Prospects

- Uncertainty remains due to lack of observational data.

- Further challenge will be

  1) improve the **observational networks**;

  2) funding more related **research projects** ;

  3) enhancing **international cooperation**.

Recent advances of Related Research In China

Operation agencies

CAS

EPA of China

CMA

Funding Agencies

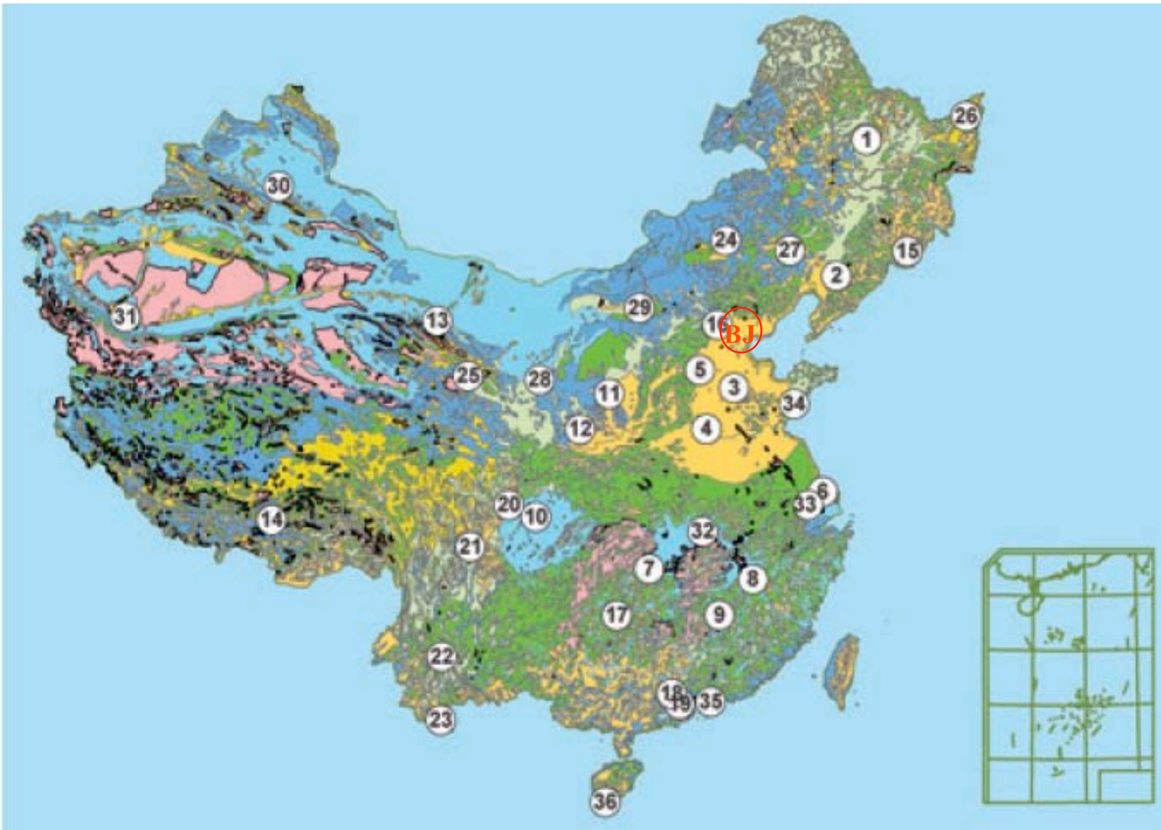
MOST

NSFC

- **The observation** Capacities and instrumentations, improved
- **Subject studies** Increased
- **International cooperation** Active than before

The observation networks

The Radiation Monitoring Network of Chinese academy of sciences

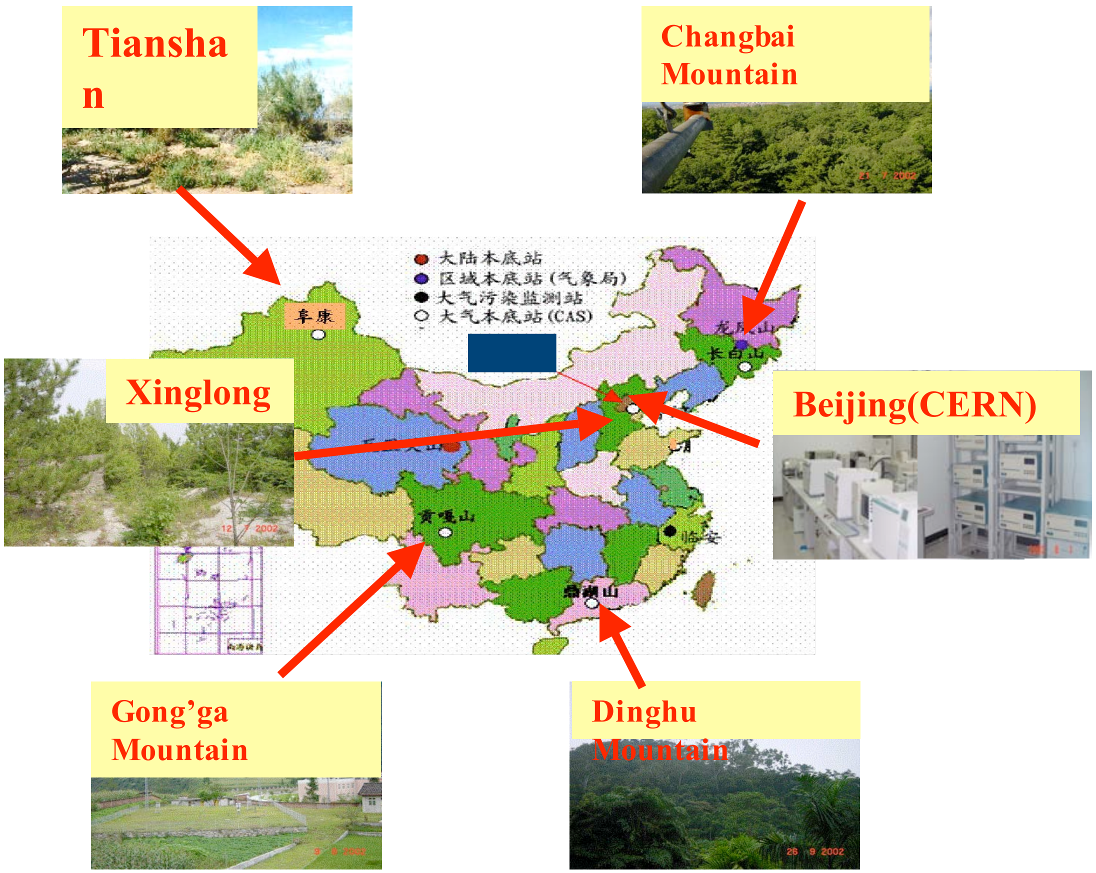


- 1-14th : Agriculture
- 15-23rd : Forest
- 24-25th : Grassland
- 26th :Marsh (Wet Lands)
- 27-31st Desert Ecosystems
- 32-33rd : Lake(fresh water)
- 34-36th Marginal Sea
- BJ metropolis station

Distributions map of ecosystem research stations of CERN

The observation networks

Network Monitoring of Aerosol Chemical Characteristics in Regional Background Atmosphere



Observatory selection under the guide of global atmosphere watch measurements

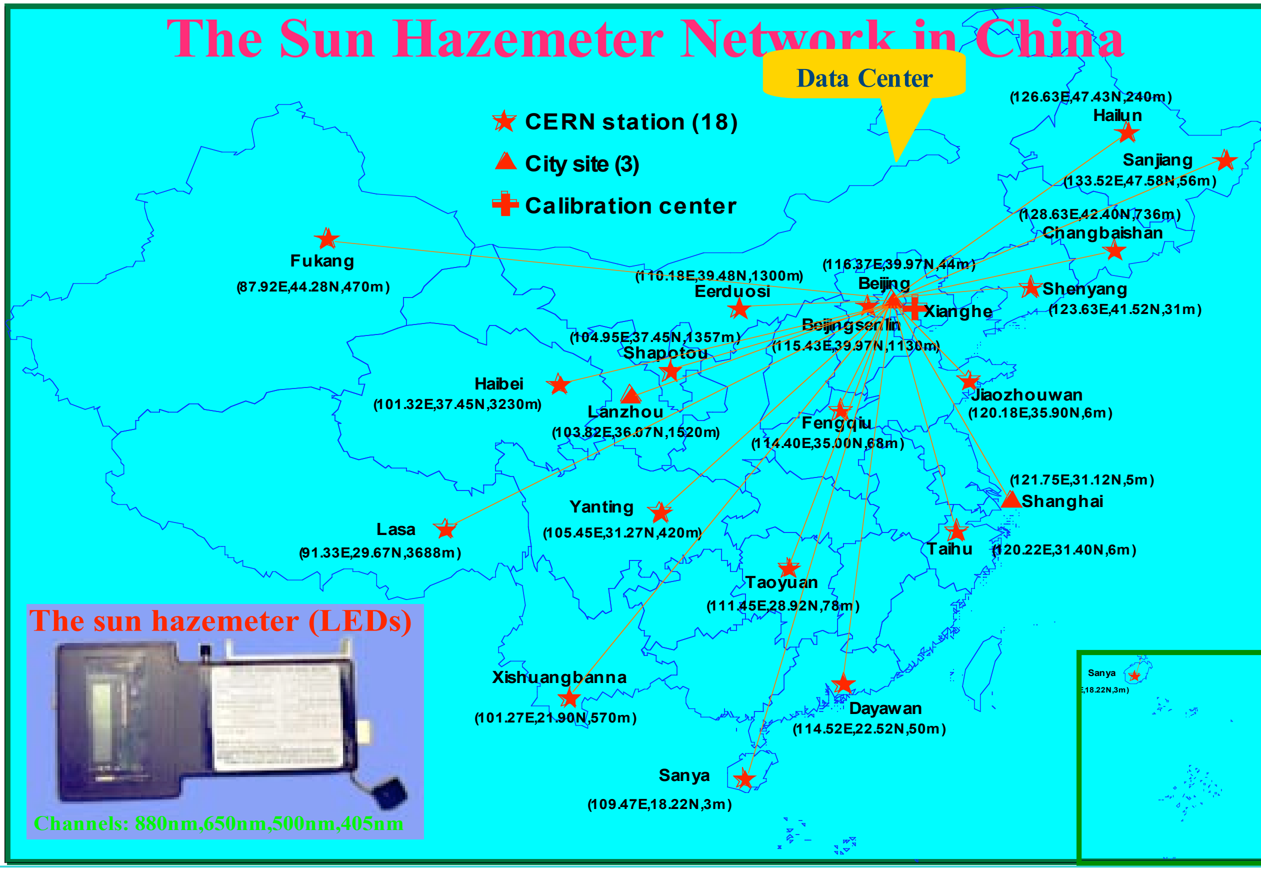
Observatories are representative of regional background in China

Distribution of Regional Background Observatory

The observation networks

The Sun Hazemeter Network in China

aerosol optical properties and spatial and temporal variation in China, and to revise the results of the satellite remote sensing



This network covers almost all of Chinese area, including 18 CERN stations, 3 typical city sites, a data collect /adjust center

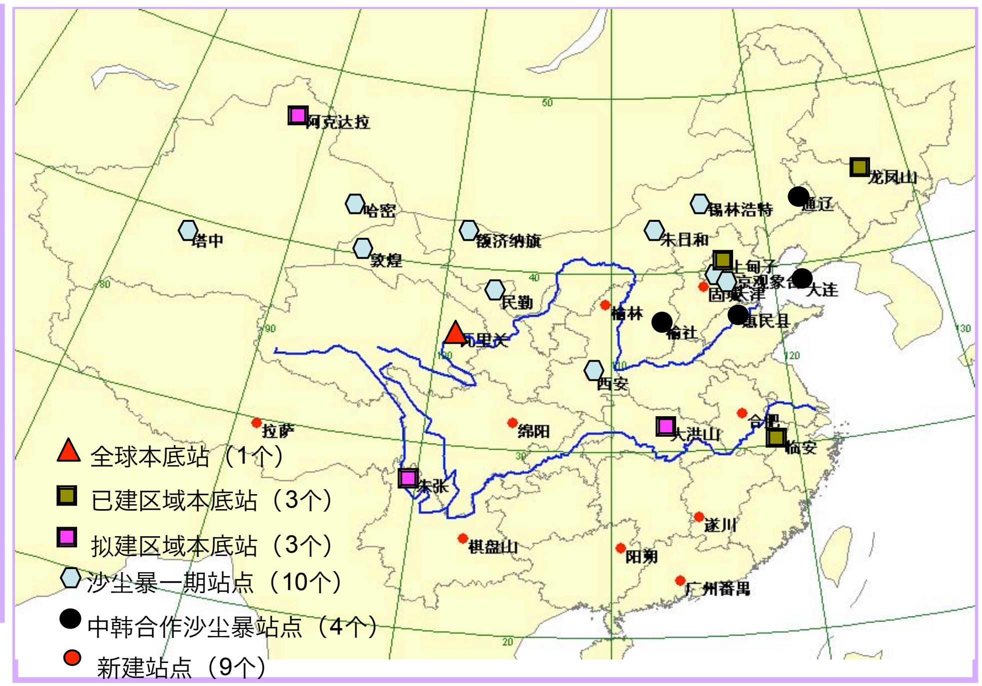
& instrument calibration center.

Agricultural Stations (6): Sanjiang, Hailun, Shenyang, Fengqiu, Yanting and Taoyuan.
Forest Station (3): Changbaishan, Beijing-Forest and Xishuangbanna. **Desert Stations (3):** Eerduosi, Shapotou and Fukang.
Marginal Sea Stations (3): Jiaozhou Bay, Daya Bay and Sanya. **Lake Stations (1):** Taihu.
Plateau Stations (2): Haibei Grassland and Lasa. **Typical City Sites (3):** Lanzhou, Beijing and Shanghai.

The observation networks

Sunphotometer Network (2005),25 stations

PM10 & Aethalometer Network (2005)

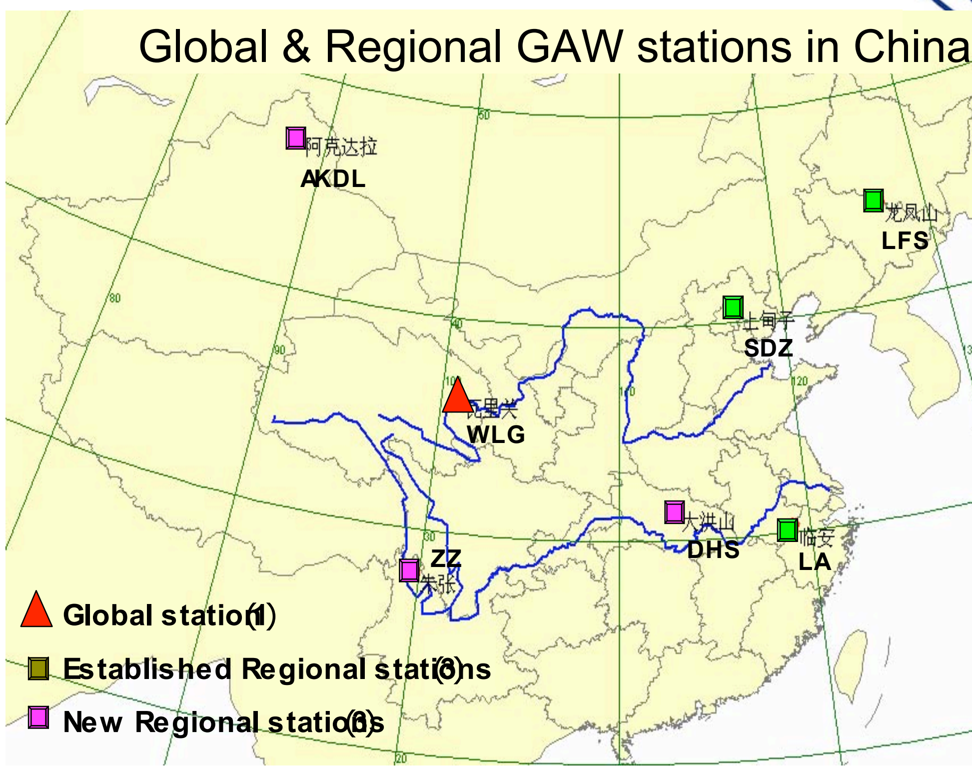


The observation networks

CAWAS mission & structure

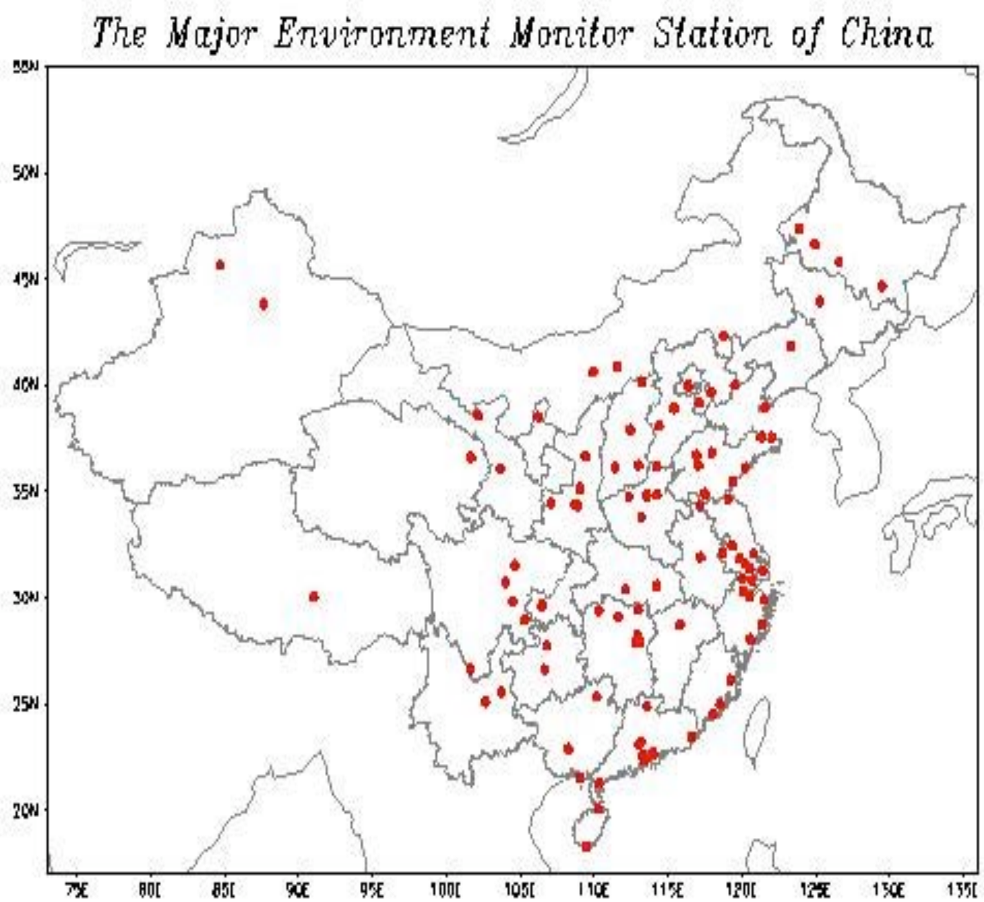
Atmospheric chemistry observations (including GAW stations), research & forecasting in CMA operated by CAWAS

An essential & promoting part of the GAW and IGACO.



The observation networks

The Environment Monitor Stations of China



(ZHB, 2004)

China has 340 environment monitor stations:

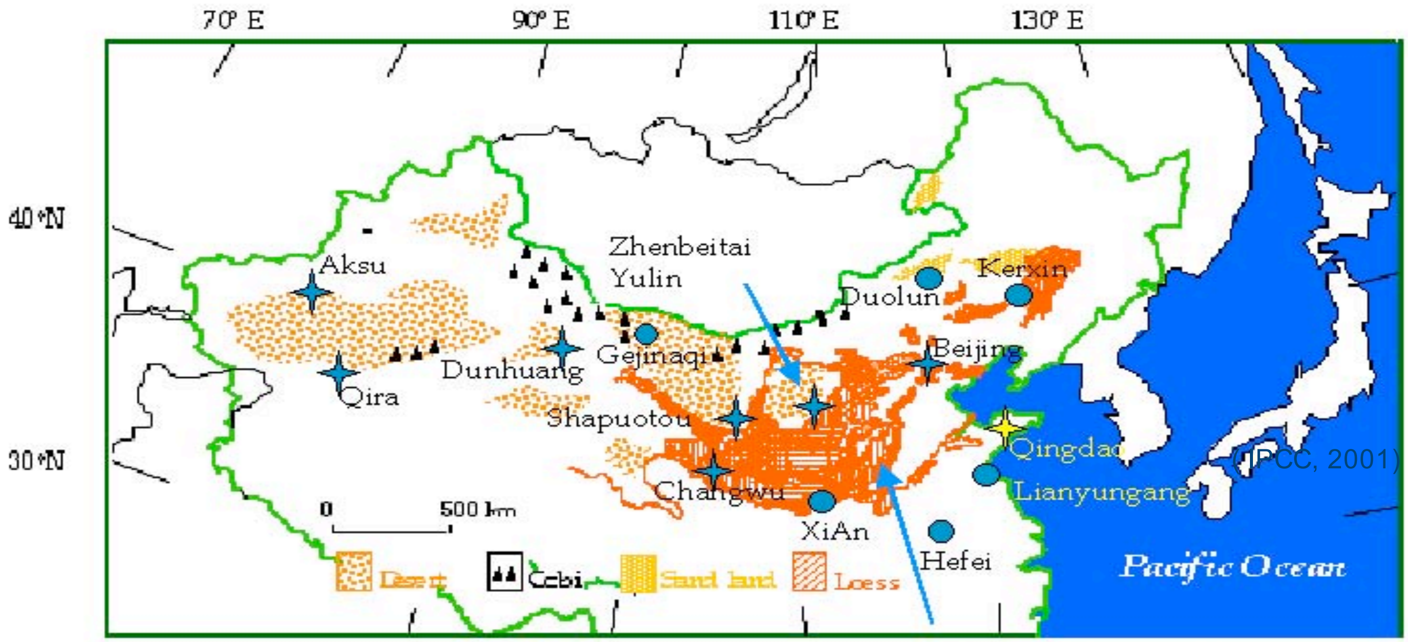
TSP, trace gas such as ozone, SO_2, NO_2 and CO

Subject Studies

Asia soil dust and its regional and global impacts to the climate and environment PI:Xiaoye zhang

Asian soil dust_Network Observation

亚洲粉尘联合观测网站点（2001年起连续观测、采样）



Funds: (KZCX2-305) from CAS; G2000048703 from MOST; ADEC from CAS

Chinese Loess Plateau (100 to 200 m in depth)

Subject Studies

Processes of regional complex pollution and three-dimensional observation, Funds: 2002CB410801
PI:Yuanhang Zhang

Subject Studies

•The mechanism of Soil dust's form,transportation and impacts to climate and environment

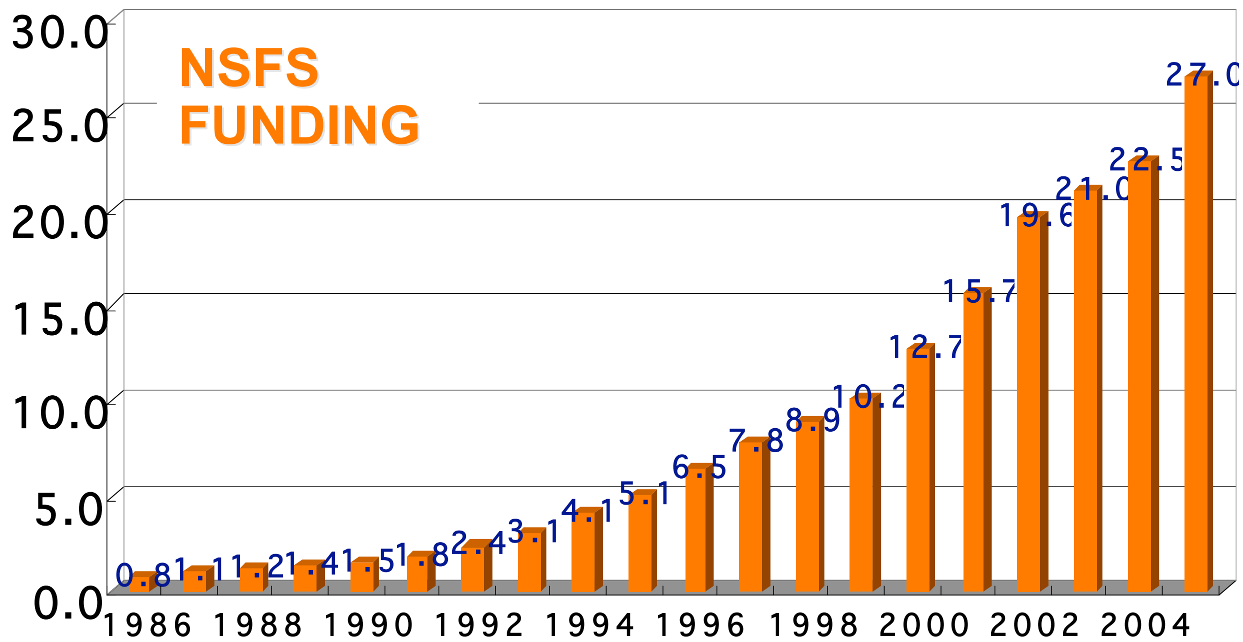
PI:Guangyu Shi

•Simulation of dust transportation and effects to climate and environment

PI:Zifa Wang

•…

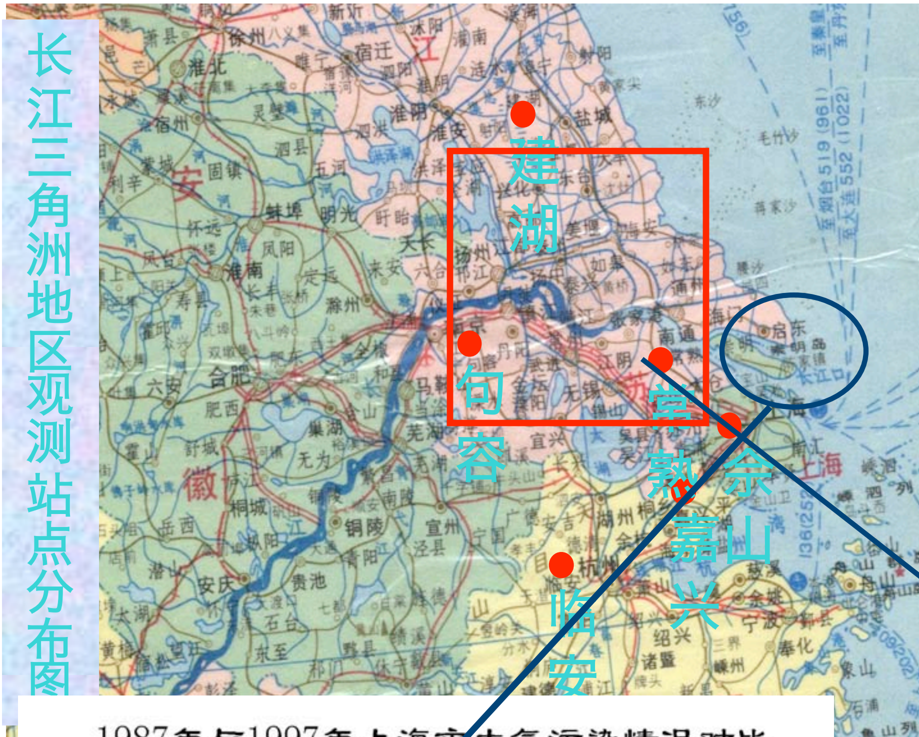
Subject Studies

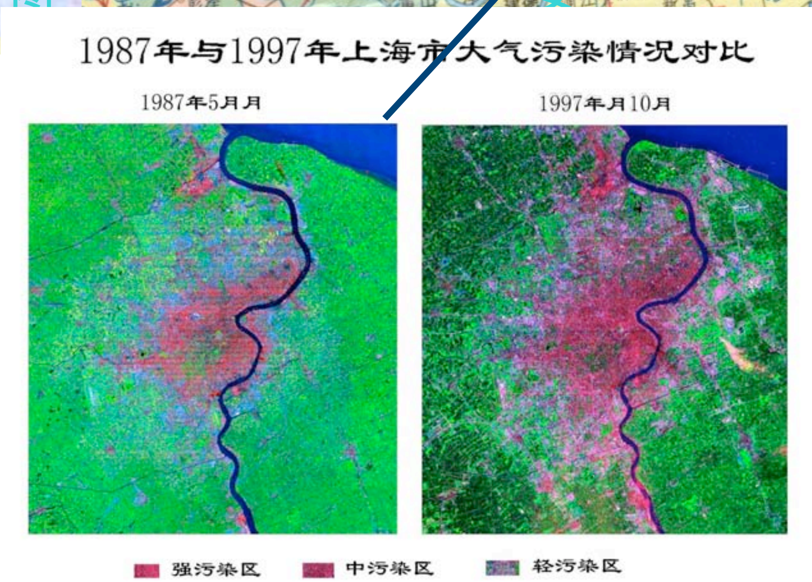


19 years, 34 times increase

Projects in this topics have being increasing,which involved many aspects of aerosols and climate,
even aircraft observation of aerosol’s indirect effect

Subject Studies



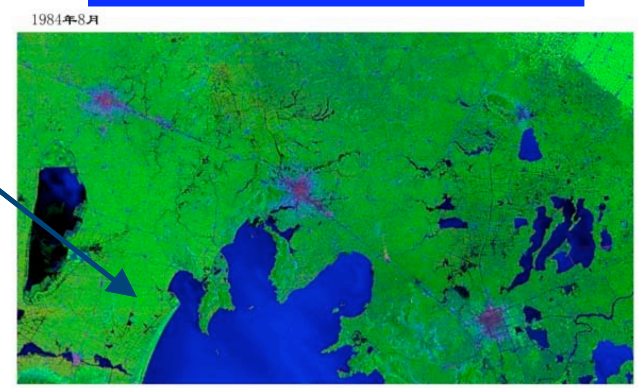


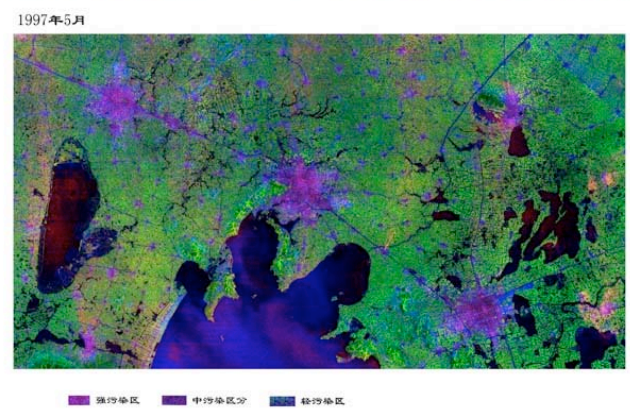
e Forcing

NSFC Major Project— The Physical-Chemical Process Of The Lower Atmosphere And Ecological System Interactive Effect In Yangtze Delta

5 Millions.

Day time O_3 34.7-47.7ppb
lower limit 30ppb





Subject Studies

Projects closed to aerosols and climate forcing Funded by NSFC

	Num.	Title	Type	Start date	Expires	PI	Sponsor	Funds
1	48870211	Aerosol optical properties and climate effect	A	1989.01	1991.12	___	____	4.5
2	49635200	The radiative characteristics of atmospheric aerosol over China	F	1997.01	2000.12	___	____	120
3	49675250	Impacts of chemical component and atmospheric environment on radiative characteristics of aerosol	A	1997.01	1999.12	___	______ __	14
4	49675272	Interaction of city aerosol and boundary layer in Lanzhou	A	1997.01	1999.12	___	____	9
5	49775274	Observational study on Black Carbon aerosol in China typical area	A	1998.01	2000.12	__	______ ___	15
6	49775275	Observational study on ozone and aerosol in Tibetan Plateau	A	1998.01	2000.12	___	______	28
7	49875027	Retrieval urban aerosols from satellite data	A	1999.01	2002.12	___	____	18
8	40075025	The physical and chemical properties study of aerosols in the Lanzhou region	A	2001.01	2003.12			19

Subject Studies

N S F C

Projects closed to aerosols and climate forcing Funded by NSFC

9	40175009	Satellite remote sensing of aerosol optical properties and surface reflectance	A	2002.01	2004.12	___	______	26
10	40205006	Baseborn remote sensing methods of aerosol optical properties and application	C	2003.01	2003.12	___	______	8
11	40205016	The study on the climate effects of aerosols using combined climate and chemical model system	C	2003.01	2005.12	__	____	18
12	40205017	Research on the physical and chemical characteristics of aerosols and their impact on atmospheric environment in Eastern China	C	2003.01	2005.12	___	______	28
13	40205018	Characterization and source apportionment of atmospheric carbonaceous aerosol over Asia dust source regions	C	2003.01	2005.12	___	______ ____	26
14	40275039	Atmospheric aerosol radiative forcing and interaction of meteorological fields	A	2003.01	2005.12	__	____	40
15	40305002	Ground and satellite remote sensing of aerosol direct radiative forcing in China	C	2004.01	2006.12	___	______	26
16	40305018	Mechanism of the mixing aerosols change during transport over East Asia	C	2004.01	2006.12			31

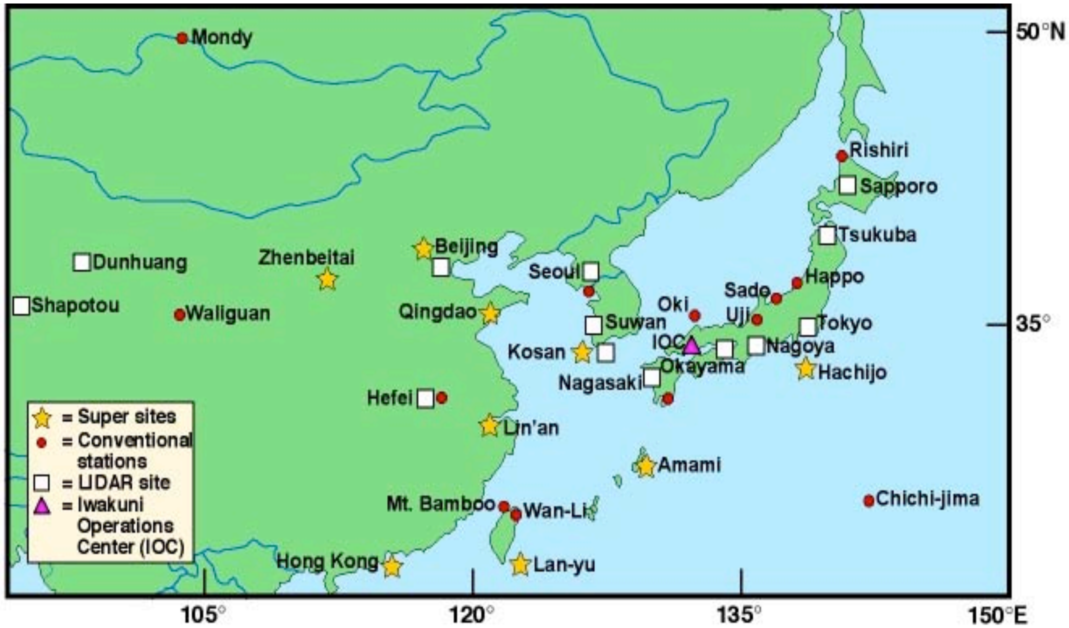
Subject Studies

NSFC

Projects closed to aerosols and climate forcing Funded by NSFC

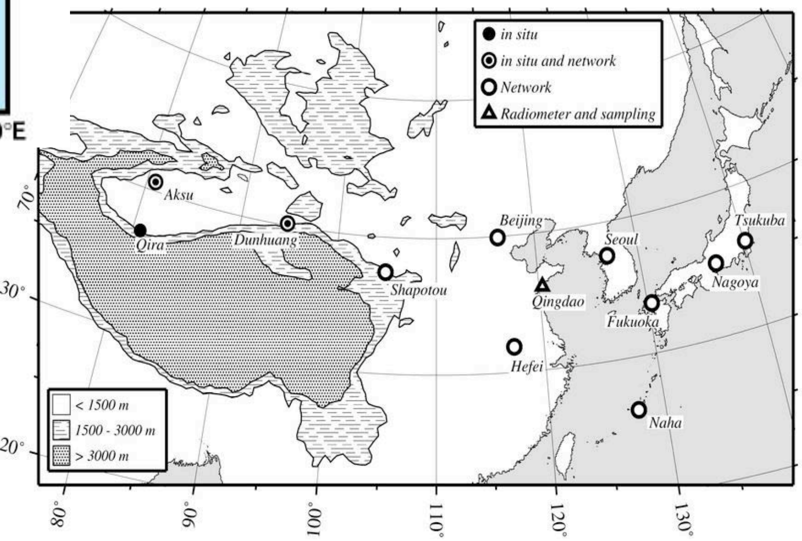
17	40333029	Temporal-spatial distributions of aerosol and cloud optical properties in China	F	2004.01	2007.12	___	______	130
18	40375002	A study on observation of radiative characteristics of atmospheric aerosol of regional city group in Pearl River Delta	A	2004.01	2006.12	__	______ _____	35
19	40375003	Effects of dust aerosols on the evolution of precipitation	A	2004.01	2006.12	__	______ __	36
20	40375040	Impacts of megacity emissions on regional distributions of aerosols in the Yangtze Delta	A	2004.01	2006.12	___	______ _	26
21	40375042	Observational study on physical and chemical characteristic of particle pollution over Beijing area	A	2004.05	2006.12	___	______	37
22	40475008	Effects of internal mixture of aerosol in water droplet on the optical properties	A	2005.01	2005.12	__	______	10
23	40405013	The modeling of drought and flood anomaly over China in the influence of Black Carbon aerosol	A	2005.01	2007.12	___	______	25.5
24	40433008	Effects of air pollution on aerosols and cloud microphysics in North China	F	2005.01	2008.12		______	180

International cooperation



ADEC

Aeolian Dust Experiment on Climate Impact



(ACE-Asia, 2001)

Japan-Sino Joint Project

Initiated in April 2000 (to 2005)

China-US Joint Project (2005-2007):

Study of Aerosol Characteristics over China

20 of 35 CERN stations equipped with handheld sunphotometers for measuring AOT

Next five years (2006-2010), NSFC total fund over 20 B. Double to recent former five years (2001-2005)

We are now conducting the Priorities of next 5-10 years,

"Aerosols-Cloud-Radiation-Climate"

Will be one of the Priorities in next 5-10 years in NSF of China

National or international coordination and cooperation are important for communities in this research areas

NSFC

Thank you!